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Understanding [Embedded - FPGAs \(Field Programmable Gate Array\)](#)

Embedded - FPGAs, or Field Programmable Gate Arrays, are advanced integrated circuits that offer unparalleled flexibility and performance for digital systems. Unlike traditional fixed-function logic devices, FPGAs can be programmed and reprogrammed to execute a wide array of logical operations, enabling customized functionality tailored to specific applications. This reprogrammability allows developers to iterate designs quickly and implement complex functions without the need for custom hardware.

Applications of Embedded - FPGAs

The versatility of Embedded - FPGAs makes them indispensable in numerous fields. In telecommunications.

Details

Product Status	Active
Number of LABs/CLBs	3000
Number of Logic Elements/Cells	12000
Total RAM Bits	589824
Number of I/O	197
Number of Gates	-
Voltage - Supply	1.045V ~ 1.155V
Mounting Type	Surface Mount
Operating Temperature	0°C ~ 85°C (TJ)
Package / Case	256-LFBGA
Supplier Device Package	256-CABGA (14x14)
Purchase URL	https://www.e-xfl.com/product-detail/lattice-semiconductor/lfe5u-12f-6bg256c

Tables

Table 1.1. ECP5 and ECP5-5G Family Selection Guide	11
Table 2.1. Resources and Modes Available per Slice	14
Table 2.2. Slice Signal Descriptions	16
Table 2.3. Number of Slices Required to Implement Distributed RAM	17
Table 2.4. PLL Blocks Signal Descriptions	19
Table 2.5. DDRDLL Ports List	23
Table 2.6. sysMEM Block Configurations	25
Table 2.7. Maximum Number of Elements in a Slice	30
Table 2.8. Input Block Port Description	33
Table 2.9. Output Block Port Description	34
Table 2.10. Tristate Block Port Description	35
Table 2.11. DQSBUF Port List Description	37
Table 2.12. On-Chip Termination Options for Input Modes	40
Table 2.13. LFE5UM/LFE5UM5G SERDES Standard Support	42
Table 2.14. Available SERDES Duals per LFE5UM/LFE5UM5G Devices	43
Table 2.15. LFE5UM/LFE5UM5G Mixed Protocol Support	44
Table 2.16. Selectable Master Clock (MCLK) Frequencies during Configuration (Nominal)	46
Table 3.1. Absolute Maximum Ratings	47
Table 3.2. Recommended Operating Conditions	47
Table 3.3. Power Supply Ramp Rates	48
Table 3.4. Power-On-Reset Voltage Levels	48
Table 3.5. Hot Socketing Specifications	48
Table 3.6. Hot Socketing Requirements	49
Table 3.7. DC Electrical Characteristics	49
Table 3.8. ECP5/ECP5-5G Supply Current (Standby)	50
Table 3.9. ECP5UM	51
Table 3.10. ECP5-5G	52
Table 3.11. sysI/O Recommended Operating Conditions	53
Table 3.12. Single-Ended DC Characteristics	54
Table 3.13. LVDS	55
Table 3.14. LVDS25E DC Conditions	56
Table 3.15. BLVDS25 DC Conditions	57
Table 3.16. LVPECL33 DC Conditions	58
Table 3.17. MLVDS25 DC Conditions	59
Table 3.18. Input to SLVS	60
Table 3.19. Pin-to-Pin Performance	61
Table 3.20. Register-to-Register Performance	62
Table 3.21. ECP5/ECP5-5G Maximum I/O Buffer Speed	63
Table 3.22. ECP5/ECP5-5G External Switching Characteristics	64
Table 3.23. sysCLOCK PLL Timing	71
Table 3.24. Serial Output Timing and Levels	72
Table 3.25. Channel Output Jitter	72
Table 3.26. SERDES/PCS Latency Breakdown	73
Table 3.27. Serial Input Data Specifications	74
Table 3.28. Receiver Total Jitter Tolerance Specification	74
Table 3.29. External Reference Clock Specification (refclkp/refclkn)	75
Table 3.30. PCIe (2.5 Gb/s)	76
Table 3.31. PCIe (5 Gb/s)	77
Table 3.32. CPRI LV2 E.48 Electrical and Timing Characteristics	79
Table 3.33. Transmit	80
Table 3.34. Receive and Jitter Tolerance	80
Table 3.35. Transmit	80

1. General Description

The ECP5/ECP5-5G family of FPGA devices is optimized to deliver high performance features such as an enhanced DSP architecture, high speed SERDES (Serializer/Deserializer), and high speed source synchronous interfaces, in an economical FPGA fabric. This combination is achieved through advances in device architecture and the use of 40 nm technology making the devices suitable for high-volume, high-speed, and low-cost applications.

The ECP5/ECP5-5G device family covers look-up-table (LUT) capacity to 84K logic elements and supports up to 365 user I/Os. The ECP5/ECP5-5G device family also offers up to 156 18 x 18 multipliers and a wide range of parallel I/O standards.

The ECP5/ECP5-5G FPGA fabric is optimized high performance with low power and low cost in mind. The ECP5/ECP5-5G devices utilize reconfigurable SRAM logic technology and provide popular building blocks such as LUT-based logic, distributed and embedded memory, Phase-Locked Loops (PLLs), Delay-Locked Loops (DLLs), pre-engineered source synchronous I/O support, enhanced sysDSP slices and advanced configuration support, including encryption and dual-boot capabilities.

The pre-engineered source synchronous logic implemented in the ECP5/ECP5-5G device family supports a broad range of interface standards including DDR2/3, LPDDR2/3, XGMII, and 7:1 LVDS.

The ECP5/ECP5-5G device family also features high speed SERDES with dedicated Physical Coding Sublayer (PCS) functions. High jitter tolerance and low transmit jitter allow the SERDES plus PCS blocks to be configured to support an array of popular data protocols including PCI Express, Ethernet (XAUI, GbE, and SGMII) and CPRI. Transmit De-emphasis with pre- and post-cursors, and Receive Equalization settings make the SERDES suitable for transmission and reception over various forms of media.

The ECP5/ECP5-5G devices also provide flexible, reliable and secure configuration options, such as dual-boot capability, bit-stream encryption, and TransFR field upgrade features.

ECP5-5G family devices have made some enhancement in the SERDES compared to ECP5UM devices. These enhancements increase the performance of the SERDES to up to 5 Gb/s data rate.

The ECP5-5G family devices are pin-to-pin compatible with the ECP5UM devices. These allows a migration path for users to port designs from ECP5UM to ECP5-5G devices to get higher performance.

The Lattice Diamond™ design software allows large complex designs to be efficiently implemented using the ECP5/ECP5-5G FPGA family. Synthesis library support for ECP5/ECP5-5G devices is available for popular logic synthesis tools. The Diamond tools use the synthesis tool output along with the constraints from its floor planning tools to place and route the design in the ECP5/ECP5-5G device. The tools extract the timing from the routing and back-annotate it into the design for timing verification.

Lattice provides many pre-engineered IP (Intellectual Property) modules for the ECP5/ECP5-5G family. By using these configurable soft core IPs as standardized blocks, designers are free to concentrate on the unique aspects of their design, increasing their productivity.

1.1. Features

- Higher Logic Density for Increased System Integration
 - 12K to 84K LUTs
 - 197 to 365 user programmable I/Os
- Embedded SERDES
 - 270 Mb/s, up to 3.2 Gb/s, SERDES interface (ECP5)
 - 270 Mb/s, up to 5.0 Gb/s, SERDES interface (ECP5-5G)
 - Supports eDP in RDR (1.62 Gb/s) and HDR (2.7 Gb/s)
 - Up to four channels per device: PCI Express, Ethernet (1GbE, SGMII, XAUI), and CPRI
- sysDSP™
 - Fully cascadable slice architecture
 - 12 to 160 slices for high performance multiply and accumulate
 - Powerful 54-bit ALU operations
 - Time Division Multiplexing MAC Sharing
 - Rounding and truncation
 - Each slice supports
 - Half 36 x 36, two 18 x 18 or four 9 x 9 multipliers
 - Advanced 18 x 36 MAC and 18 x 18 Multiply-Multiply-Accumulate (MMAC) operations
- Flexible Memory Resources
 - Up to 3.744 Mb sysMEM™ Embedded Block RAM (EBR)
 - 194K to 669K bits distributed RAM
- sysCLOCK Analog PLLs and DLLs

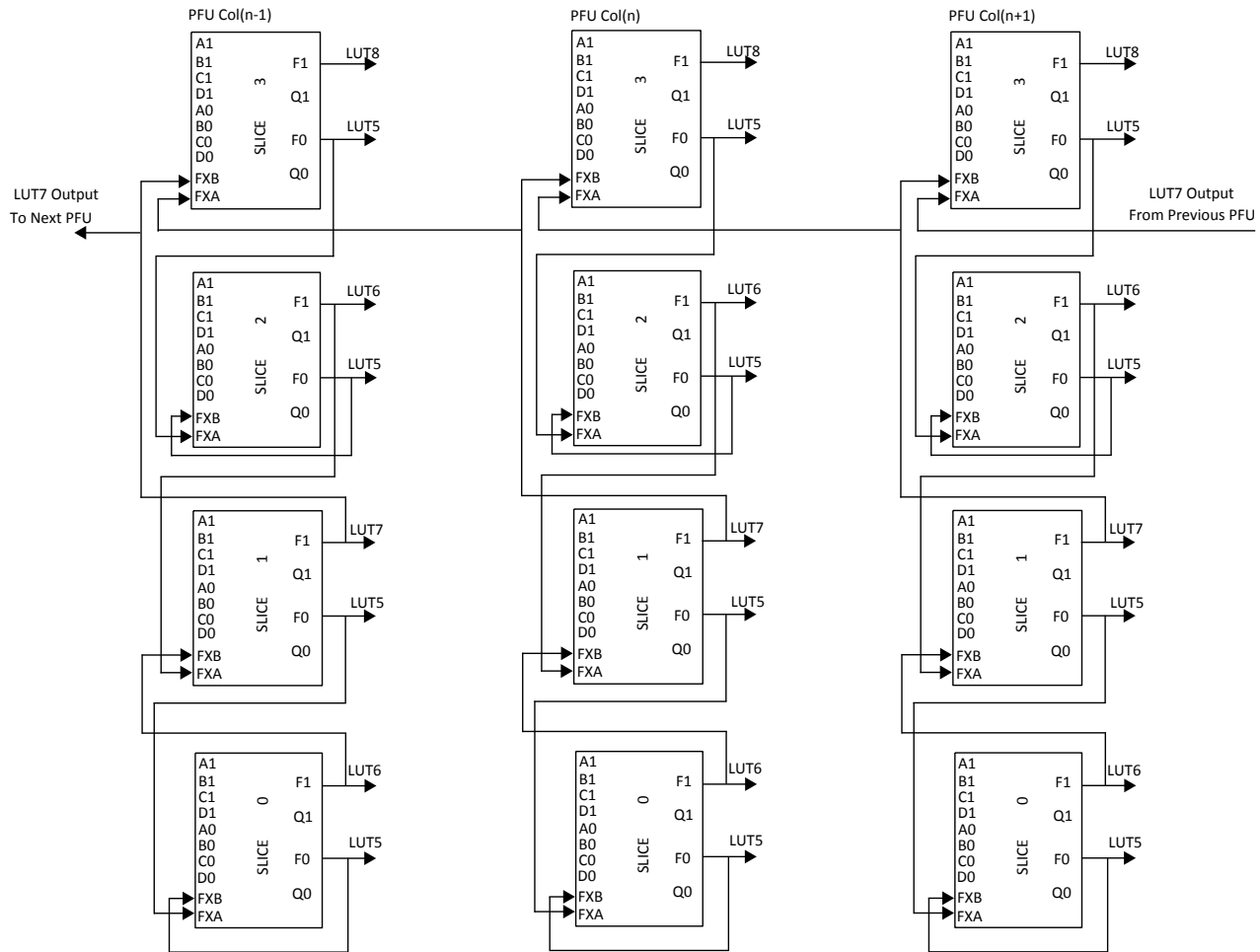


Figure 2.4. Connectivity Supporting LUT5, LUT6, LUT7, and LUT8

Table 2.2. Slice Signal Descriptions

Function	Type	Signal Names	Description
Input	Data signal	A0, B0, C0, D0	Inputs to LUT4
Input	Data signal	A1, B1, C1, D1	Inputs to LUT4
Input	Multi-purpose	M0	Multipurpose Input
Input	Multi-purpose	M1	Multipurpose Input
Input	Control signal	CE	Clock Enable
Input	Control signal	LSR	Local Set/Reset
Input	Control signal	CLK	System Clock
Input	Inter-PFU signal	FCI	Fast Carry-in ¹
Input	Inter-slice signal	FXA	Intermediate signal to generate LUT6, LUT7 and LUT8 ²
Input	Inter-slice signal	FXB	Intermediate signal to generate LUT6, LUT7 and LUT8 ²
Output	Data signals	F0, F1	LUT4 output register bypass signals
Output	Data signals	Q0, Q1	Register outputs
Output	Inter-PFU signal	FCO	Fast carry chain output ¹

Notes:

1. See [Figure 2.3](#) on page 15 for connection details.
2. Requires two adjacent PFUs.

Table 2.6. sysMEM Block Configurations

Memory Mode	Configurations
Single Port	16,384 x 1
	8,192 x 2
	4,096 x 4
	2,048 x 9
	1,024 x 18
	512 x 36
True Dual Port	16,384 x 1
	8,192 x 2
	4,096 x 4
	2,048 x 9
	1,024 x 18
Pseudo Dual Port	16,384 x 1
	8,192 x 2
	4,096 x 4
	2,048 x 9
	1,024 x 18
	512 x 36

2.8.2. Bus Size Matching

All of the multi-port memory modes support different widths on each of the ports. The RAM bits are mapped LSB word 0 to MSB word 0, LSB word 1 to MSB word 1, and so on. Although the word size and number of words for each port varies, this mapping scheme applies to each port.

2.8.3. RAM Initialization and ROM Operation

If desired, the contents of the RAM can be pre-loaded during device configuration. By preloading the RAM block during the chip configuration cycle and disabling the write controls, the sysMEM block can also be utilized as a ROM.

2.8.4. Memory Cascading

Larger and deeper blocks of RAM can be created using EBR sysMEM Blocks. Typically, the Lattice design tools cascade memory transparently, based on specific design inputs.

2.8.5. Single, Dual and Pseudo-Dual Port Modes

In all the sysMEM RAM modes the input data and address for the ports are registered at the input of the memory array. The output data of the memory is optionally registered at the output.

EBR memory supports the following forms of write behavior for single port or dual port operation:

- **Normal** – Data on the output appears only during a read cycle. During a write cycle, the data (at the current address) does not appear on the output. This mode is supported for all data widths.
- **Write Through** – A copy of the input data appears at the output of the same port during a write cycle. This mode is supported for all data widths.
- **Read-Before-Write** – When new data is written, the old content of the address appears at the output. This mode is supported for x9, x18, and x36 data widths.

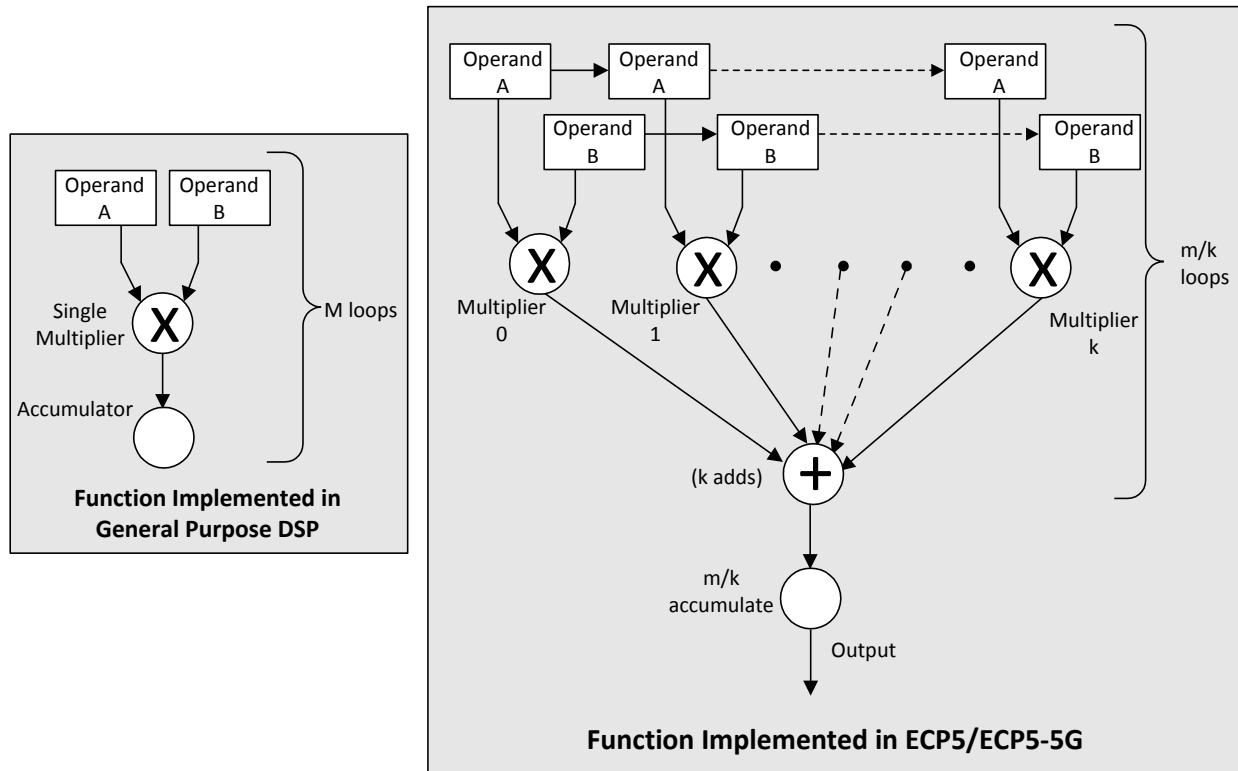


Figure 2.13. Comparison of General DSP and ECP5/ECP5-5G Approaches

2.9.2. sysDSP Slice Architecture Features

The ECP5/ECP5-5G sysDSP Slice has been significantly enhanced to provide functions needed for advanced processing applications. These enhancements provide improved flexibility and resource utilization.

The ECP5/ECP5-5G sysDSP Slice supports many functions that include the following:

- Symmetry support. The primary target application is wireless. 1D Symmetry is useful for many applications that use FIR filters when their coefficients have symmetry or asymmetry characteristics. The main motivation for using 1D symmetry is cost/size optimization. The expected size reduction is up to 2x.
 - Odd mode – Filter with Odd number of taps
 - Even mode – Filter with Even number of taps
 - Two dimensional (2D) symmetry mode – supports 2D filters for mainly video applications
- Dual-multiplier architecture. Lower accumulator overhead to half and the latency to half compared to single multiplier architecture
- Fully cascable DSP across slices. Support for symmetric, asymmetric and non-symmetric filters.
- Multiply (one 18x36, two 18x18 or four 9x9 Multiplies per Slice)
- Multiply (36x36 by cascading across two sysDSP slices)
- Multiply Accumulate (supports one 18x36 multiplier result accumulation or two 18x18 multiplier result accumulation)
- Two Multiplies feeding one Accumulate per cycle for increased processing with lower latency (two 18x18 Multiplies feed into an accumulator that can accumulate up to 52 bits)
- Pipeline registers
- 1D Symmetry support. The coefficients of FIR filters have symmetry or negative symmetry characteristics.
 - Odd mode – Filter with Odd number of taps
 - Even mode – Filter with Even number of taps
- 2D Symmetry support. The coefficients of 2D FIR filters have symmetry or negative symmetry characteristics.
 - 3*3 and 3*5 – Internal DSP Slice support

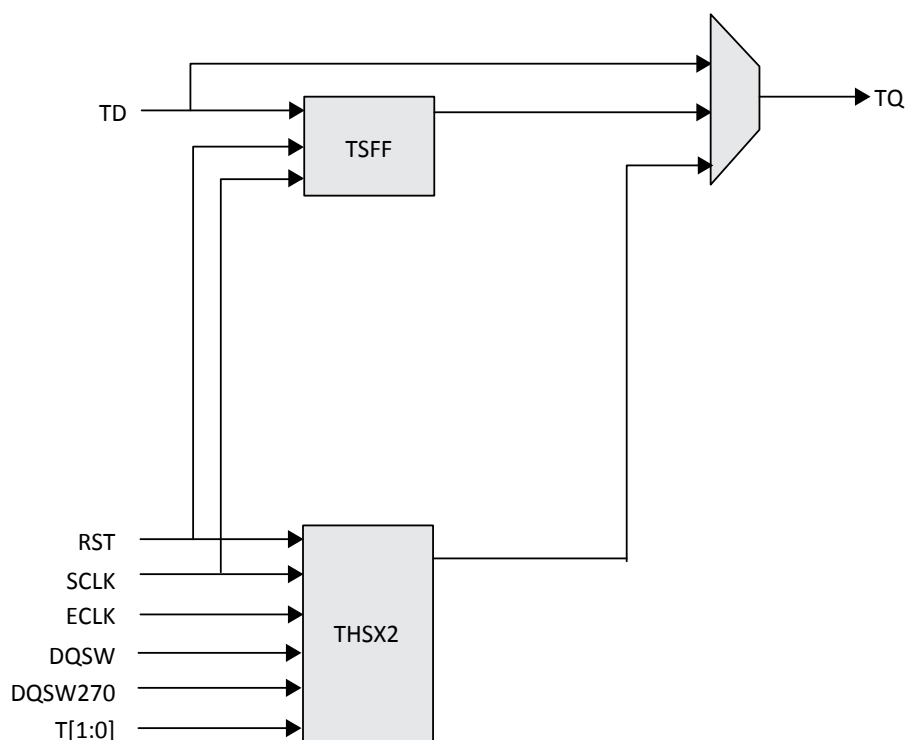


Figure 2.22. Tristate Register Block on Left and Right Sides

Table 2.10. Tristate Block Port Description

Name	Type	Description
TD	Input	Tristate Input to Tristate SDR Register
RST	Input	Reset to the Tristate Block
TD[1:0]	Input	Tristate input to TSHX2 function
SCLK	Input	Slow Speed System Clock
ECLK	Input	High Speed Edge Clock
DQSW	Input	Clock from DQS control Block used to generate DDR memory DQS output
DQSW270	Input	Clock from DQS control Block used to generate DDR memory DQ output
TQ	Output	Output of the Tristate block

2.13. DDR Memory Support

2.13.1. DQS Grouping for DDR Memory

Certain PICs have additional circuitry to allow the implementation of high-speed source synchronous and DDR2, DDR3, LPDDR2 or LPDDR3 memory interfaces. The support varies by the edge of the device as detailed below.

The left and right sides of the PIC have fully functional elements supporting DDR2, DDR3, LPDDR2 or LPDDR3 memory interfaces. Every 16 PIOs on the left and right sides are grouped into one DQS group, as shown in [Figure 2.23](#) on page 36. Within each DQS group, there are two pre-placed pins for DQS and DQS# signals. The rest of the pins in the DQS group can be used as DQ signals and DM signal. The number of pins in each DQS group bonded out is package dependent. DQS groups with less than 11 pins bonded out can only be used for LPDDR2/3 Command/ Address busses. In DQS groups with more than 11 pins bonded out, up to two pre-defined pins are assigned to be used as "virtual" VCCIO, by driving these pins to HIGH, with the user connecting these pins to VCCIO power supply. These connections create "soft" connections to VCCIO thru these output pins, and make better connections on VCCIO to help to reduce SSO noise. For details, refer to [ECP5 and ECP5-5G High-Speed I/O Interface \(TN1265\)](#).

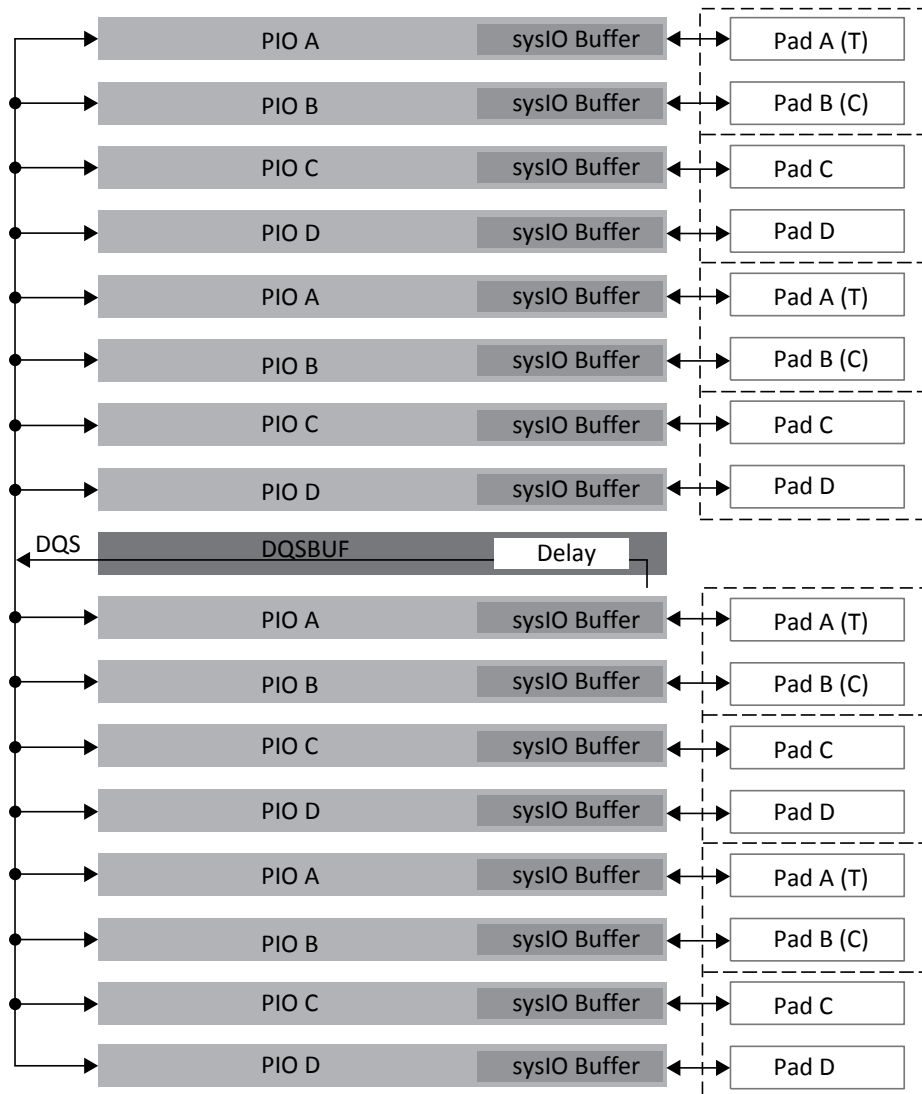


Figure 2.23. DQS Grouping on the Left and Right Edges

2.13.2. DLL Calibrated DQS Delay and Control Block (DQSBUF)

To support DDR memory interfaces (DDR2/3, LPDDR2/3), the DQS strobe signal from the memory must be used to capture the data (DQ) in the PIC registers during memory reads. This signal is output from the DDR memory device aligned to data transitions and must be time shifted before it can be used to capture data in the PIC. This time shifted is achieved by using DQSDEL programmable delay line in the DQS Delay Block (DQS read circuit). The DQSDEL is implemented as a slave delay line and works in conjunction with a master DDRDLL.

This block also includes slave delay line to generate delayed clocks used in the write side to generate DQ and DQS with correct phases within one DQS group. There is a third delay line inside this block used to provide write leveling feature for DDR write if needed.

Each of the read and write side delays can be dynamically shifted using margin control signals that can be controlled by the core logic.

FIFO Control Block shown in [Figure 2.24](#) generates the Read and Write Pointers for the FIFO block inside the Input Register Block. These pointers are generated to control the DQS to ECLK domain crossing using the FIFO module.

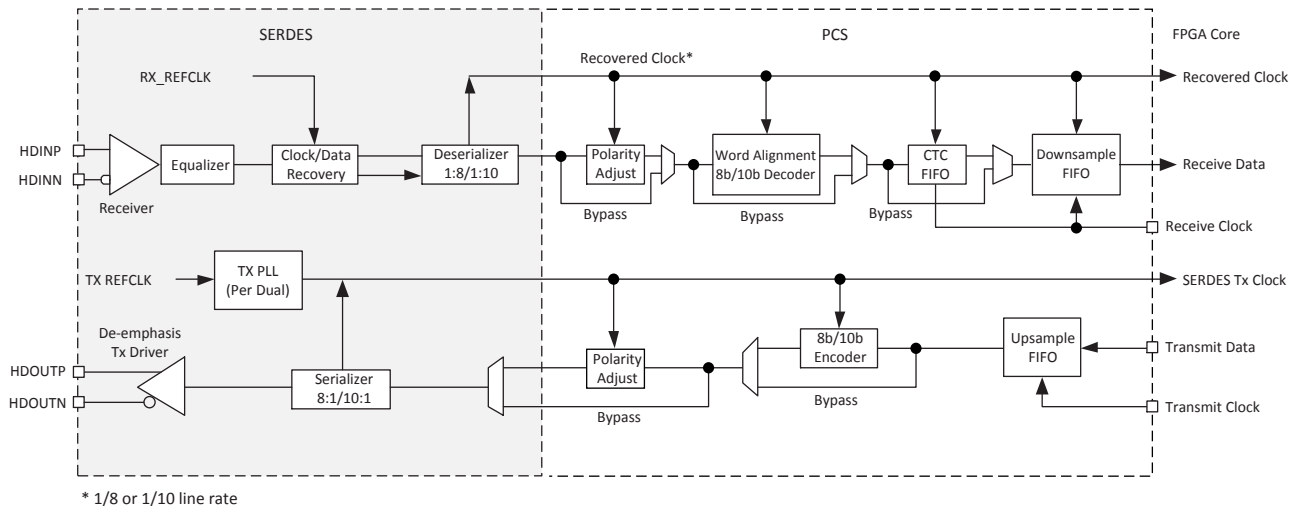
Table 2.14. Available SERDES Duals per LFE5UM/LFE5UM5G Devices

Package	LFE5UM/LFE5UM5G-25	LFE5UM/LFE5UM5G-45	LFE5UM/LFE5UM5G-85
285 csfBGA	1	1	1
381 caBGA	1	2	2
554 caBGA	—	2	2
756 caBGA	—	—	2

2.15.1. SERDES Block

A SERDES receiver channel may receive the serial differential data stream, equalize the signal, perform Clock and Data Recovery (CDR) and de-serialize the data stream before passing the 8- or 10-bit data to the PCS logic. The SERDES transmitter channel may receive the parallel 8- or 10-bit data, serialize the data and transmit the serial bit stream through the differential drivers. Figure 2.28 shows a single-channel SERDES/PCS block. Each SERDES channel provides a recovered clock and a SERDES transmit clock to the PCS block and to the FPGA core logic.

Each transmit channel, receiver channel, and SERDES PLL shares the same power supply (VCCA). The output and input buffers of each channel have their own independent power supplies (VCCHTX and VCCHRX).


Figure 2.28. Simplified Channel Block Diagram for SERDES/PCS Block

2.15.2. PCS

As shown in Figure 2.28, the PCS receives the parallel digital data from the deserializer and selects the polarity, performs word alignment, decodes (8b/10b), provides Clock Tolerance Compensation and transfers the clock domain from the recovered clock to the FPGA clock via the Down Sample FIFO.

For the transmit channel, the PCS block receives the parallel data from the FPGA core, encodes it with 8b/10b, selects the polarity and passes the 8/10 bit data to the transmit SERDES channel.

The PCS also provides bypass modes that allow a direct 8-bit or 10-bit interface from the SERDES to the FPGA logic. The PCS interface to the FPGA can also be programmed to run at 1/2 speed for a 16-bit or 20-bit interface to the FPGA logic.

Some of the enhancements in LFE5UM/LFE5UM5G SERDES/PCS include:

- Higher clock/channel granularity: Dual channel architecture provides more clock resource per channel.
- Enhanced Tx de-emphasis: Programmable pre- and post-cursors improves Tx output signaling
- Bit-slip function in PCS: Improves logic needed to perform Word Alignment function

Refer to [ECP5 and ECP5-5G SERDES/PCS Usage Guide \(TN1261\)](#) for more information.

Parameter	Description	Device	-8		-7		-6		Unit
			Min	Max	Min	Max	Min	Max	
f _{DATA_DDR2} f _{DATA_DDR3} f _{DATA_DDR3L} f _{DATA_LPDDR2} f _{DATA_LPDDR3}	DDR Memory Data Rate	All Devices	—	800	—	700	—	624	Mb/s
f _{MAX_DDR2} f _{MAX_DDR3} f _{MAX_DDR3L} f _{MAX_LPDDR2} f _{MAX_LPDDR3}	DDR Memory CLK Frequency (ECLK)	All Devices	—	400	—	350	—	312	MHz
DDR2/DDR3/DDR3L/LPDDR2/LPDDR3 WRITE (DQ Output Data are Centered to DQS)									
t _{DQVBS_DDR2} t _{DQVBS_DDR3} t _{DQVBS_DDR3L} t _{DQVBS_LPDDR2} t _{DQVBS_LPDDR3}	Data Output Valid before DQS Output	All Devices	—	–0.25	—	–0.25	—	–0.25	UI
t _{DQVAS_DDR2} t _{DQVAS_DDR3} t _{DQVAS_DDR3L} t _{DQVAS_LPDDR2} t _{DQVAS_LPDDR3}	Data Output Valid after DQS Output	All Devices	0.25	—	0.25	—	0.25	—	UI
f _{DATA_DDR2} f _{DATA_DDR3} f _{DATA_DDR3L} f _{DATA_LPDDR2} f _{DATA_LPDDR3}	DDR Memory Data Rate	All Devices	—	800	—	700	—	624	Mb/s
f _{MAX_DDR2} f _{MAX_DDR3} f _{MAX_DDR3L} f _{MAX_LPDDR2} f _{MAX_LPDDR3}	DDR Memory CLK Frequency (ECLK)	All Devices	—	400	—	350	—	312	MHz

Notes:

- Commercial timing numbers are shown. Industrial numbers are typically slower and can be extracted from the Diamond software.
- General I/O timing numbers are based on LVCMOS 2.5, 12 mA, Fast Slew Rate, 0pf load.
Generic DDR timing are numbers based on LVDS I/O.
DDR2 timing numbers are based on SSTL18.
DDR3 timing numbers are based on SSTL15.
LPDDR2 and LPDDR3 timing numbers are based on HSUL12.
- Uses LVDS I/O standard for measurements.
- Maximum clock frequencies are tested under best case conditions. System performance may vary upon the user environment.
- All numbers are generated with the Diamond software.

3.19. sysCLOCK PLL Timing

Over recommended operating conditions.

Table 3.23. sysCLOCK PLL Timing

Parameter	Descriptions	Conditions	Min	Max	Units
f_{IN}	Input Clock Frequency (CLKI, CLKFB)	—	8	400	MHz
f_{OUT}	Output Clock Frequency (CLKOP, CLKOS)	—	3.125	400	MHz
f_{VCO}	PLL VCO Frequency	—	400	800	MHz
f_{PFD}^3	Phase Detector Input Frequency	—	10	400	MHz
AC Characteristics					
t_{DT}	Output Clock Duty Cycle	—	45	55	%
t_{PH4}	Output Phase Accuracy	—	–5	5	%
t_{OPJIT}^1	Output Clock Period Jitter	$f_{OUT} \geq 100$ MHz	—	100	ps p-p
		$f_{OUT} < 100$ MHz	—	0.025	UIPP
	Output Clock Cycle-to-Cycle Jitter	$f_{OUT} \geq 100$ MHz	—	200	ps p-p
		$f_{OUT} < 100$ MHz	—	0.050	UIPP
	Output Clock Phase Jitter	$f_{PFD} \geq 100$ MHz	—	200	ps p-p
		$f_{PFD} < 100$ MHz	—	0.011	UIPP
t_{SPO}	Static Phase Offset	Divider ratio = integer	—	400	ps p-p
t_W	Output Clock Pulse Width	At 90% or 10%	0.9	—	ns
t_{LOCK}^2	PLL Lock-in Time	—	—	15	ms
t_{UNLOCK}	PLL Unlock Time	—	—	50	ns
t_{IPJIT}	Input Clock Period Jitter	$f_{PFD} \geq 20$ MHz	—	1,000	ps p-p
		$f_{PFD} < 20$ MHz	—	0.02	UIPP
t_{HI}	Input Clock High Time	90% to 90%	0.5	—	ns
t_{LO}	Input Clock Low Time	10% to 10%	0.5	—	ns
t_{RST}	RST/ Pulse Width	—	1	—	ms
t_{RSTREC}	RST Recovery Time	—	1	—	ns
t_{LOAD_REG}	Min Pulse for CIB_LOAD_REG	—	10	—	ns
$t_{ROTATE-SETUP}$	Min time for CIB dynamic phase controls to be stable fore CIB_ROTATE	—	5	—	ns
$t_{ROTATE-WD}$	Min pulse width for CIB_ROTATE to maintain “0” or	—	4	—	VCO cycles

Notes:

1. Jitter sample is taken over 10,000 samples for Periodic jitter, and 2,000 samples for Cycle-to-Cycle jitter of the primary PLL output with clean reference clock with no additional I/O toggling.
2. Output clock is valid after t_{LOCK} for PLL reset and dynamic delay adjustment.
3. Period jitter and cycle-to-cycle jitter numbers are guaranteed for $f_{PFD} > 10$ MHz. For $f_{PFD} < 10$ MHz, the jitter numbers may not be met in certain conditions.

Table 3.31. PCIe (5 Gb/s) (Continued)

Symbol	Description	Test Conditions	Min	Typ	Max	Unit
Receive^{1, 2}						
UI	Unit Interval	—	199.94	200	200.06	ps
V _{RX-DIFF-PP}	Differential Rx peak-peak voltage	—	0.34 ³	—	1.2	V, p-p
T _{RX-RJ-RMS}	Receiver random jitter tolerance (RMS)	1.5 MHz – 100 MHz Random noise	—	—	4.2	ps, RMS
T _{RX-DJ}	Receiver deterministic jitter tolerance	—	—	—	88	ps
V _{RX-CM-AC}	Common mode noise from Rx	—	—	—		mV, p-p
R _{LRX-DIFF}	Receiver differential Return Loss, package plus silicon	50 MHz < freq < 1.25 GHz	10	—	—	dB
		1.25 GHz < freq < 2.5 GHz	8	—	—	dB
R _{LRX-CM}	Receiver common mode Return Loss, package plus silicon	—	6	—	—	dB
Z _{RX-DC}	Receiver DC single ended impedance	—	40	—	60	Ω
Z _{RX-HIGH-IMP-DC}	Receiver DC single ended impedance when powered down	—	200K	—	—	Ω
V _{RX-CM-AC-P}	Rx AC peak common mode voltage	—	—	—		mV, peak
V _{RX-IDLE-DET-DIFF-PP}	Electrical Idle Detect Threshold	—	65	—	340 ³	mv,
L _{RX-SKEW}	Receiver lane-lane skew	—	—	—	8	ns

Notes:

1. Values are measured at 5 Gb/s.
2. Measured with external AC-coupling on the receiver.
3. Not in compliance with PCI Express standard.

3.26. CPRI LV2 E.48 Electrical and Timing Characteristics – Preliminary

Table 3.32. CPRI LV2 E.48 Electrical and Timing Characteristics

Symbol	Description	Test Conditions	Min	Typ	Max	Unit
Transmit						
UI	Unit Interval	—	203.43	203.45	203.47	ps
T _{DCD}	Duty Cycle Distortion	—	—	—	0.05	UI
J _{UBHPJ}	Uncorrelated Bounded High Probability Jitter	—	—	—	0.15	UI
J _{TOTAL}	Total Jitter	—	—	—	0.3	UI
Z _{RX-DIFF-DC}	DC differential Impedance	—	80	—	120	Ω
T _{SKEW}	Skew between differential signals	—	—	—	9	ps
R _{LTX-DIFF}	Tx Differential Return Loss (S22), including package and silicon	100 MHz < freq < 3.6864 GHz	—	—	–8	dB
		3.6864 GHz < freq < 4.9152 GHz	—	—	–8 + 16.6 *log (freq/3.6864)	dB
R _{LTX-CM}	Tx Common Mode Return Loss, including package and silicon	100 MHz < freq < 3.6864 GHz	6	—	—	dB
I _{TX-SHORT}	Transmitter short-circuit current	—	—	—	100	mA
T _{RISE_FALL-DIFF}	Differential Rise and Fall Time	—	—	—	—	ps
L _{TX-SKEW}	Lane-to-lane output skew	—	—	—	—	ps
Receive						
UI	Unit Interval	—	203.43	203.45	203.47	ps
V _{RX-DIFF-PP}	Differential Rx peak-peak voltage	—	—	—	1.2	V, p-p
V _{RX-EYE_Y1_Y2}	Receiver eye opening mask, Y1 and Y2	—	62.5	—	375	mV, diff
V _{RX-EYE_X1}	Receiver eye opening mask, X1	—	—	—	0.3	UI
T _{RX-TJ}	Receiver total jitter tolerance (not including sinusoidal)	—	—	—	0.6	UI
R _{LRX-DIFF}	Receiver differential Return Loss, package plus silicon	100 MHz < freq < 3.6864 GHz	—	—	–8	dB
		3.6864 GHz < freq < 4.9152 GHz	—	—	–8 + 16.6 *log (freq/3.6864)	dB
R _{LRX-CM}	Receiver common mode Return Loss, package plus silicon	—	6	—	—	dB
Z _{RX-DIFF-DC}	Receiver DC differential impedance	—	80	100	120	Ω

Note: Data is measured with PRBS7 data pattern, not with PRBS-31 pattern.

Table 3.36. Receive and Jitter Tolerance

Symbol	Description	Test Conditions	Min	Typ	Max	Unit
RL _{RX_DIFF}	Differential return loss	From 100 MHz to 2.5 GHz	10	—	—	dB
RL _{RX_CM}	Common mode return loss	From 100 MHz to 2.5 GHz	6	—	—	dB
Z _{RX_DIFF}	Differential termination resistance	—	80	100	120	Ω
J _{RX_DJ} ^{2, 3, 4}	Deterministic jitter tolerance (peak-to-peak)	—	—	—	0.37	UI
J _{RX_RJ} ^{2, 3, 4}	Random jitter tolerance (peak-to-peak)	—	—	—	0.18	UI
J _{RX_SJ} ^{2, 3, 4}	Sinusoidal jitter tolerance (peak-to-peak)	—	—	—	0.10	UI
J _{RX_TJ} ^{1, 2, 3, 4}	Total jitter tolerance (peak-to-peak)	—	—	—	0.65	UI
T _{RX_EYE}	Receiver eye opening	—	0.35	—	—	UI

Notes:

1. Total jitter includes deterministic jitter, random jitter and sinusoidal jitter.
2. Jitter values are measured with each high-speed input AC coupled into a 50 Ω impedance.
3. Jitter and skew are specified between differential crossings of the 50% threshold of the reference signal.
4. Jitter tolerance, Differential Input Sensitivity and Receiver Eye Opening parameters are characterized when Full Rx Equalization is enabled.

3.29. Gigabit Ethernet/SGMII(1.25Gbps)/CPRI LV E.12 Electrical and Timing Characteristics

3.29.1. AC and DC Characteristics

Table 3.37. Transmit

Symbol	Description	Test Conditions	Min	Typ	Max	Unit
T _{RF}	Differential rise/fall time	20% to 80%	—	80	—	ps
Z _{TX_DIFF_DC}	Differential impedance	—	80	100	120	Ω
J _{TX_DDJ} ^{2, 3}	Output data deterministic jitter	—	—	—	0.10	UI
J _{TX_TJ} ^{1, 2, 3}	Total output data jitter	—	—	—	0.24	UI

Notes:

1. Total jitter includes both deterministic jitter and random jitter. The random jitter is the total jitter minus the actual deterministic jitter.
2. Jitter values are measured with each CML output AC coupled into a 50 Ω impedance (100 Ω differential impedance).
3. Jitter and skew are specified between differential crossings of the 50% threshold of the reference signal.

Table 3.38. Receive and Jitter Tolerance

Symbol	Description	Test Conditions	Min	Typ	Max	Unit
RL _{RX_DIFF}	Differential return loss	From 100 MHz to 1.25 GHz	10	—	—	dB
RL _{RX_CM}	Common mode return loss	From 100 MHz to 1.25 GHz	6	—	—	dB
Z _{RX_DIFF}	Differential termination resistance	—	80	100	120	Ω
J _{RX_DJ} ^{1, 2, 3, 4}	Deterministic jitter tolerance (peak-to-peak)	—	—	—	0.34	UI
J _{RX_RJ} ^{1, 2, 3, 4}	Random jitter tolerance (peak-to-peak)	—	—	—	0.26	UI
J _{RX_SJ} ^{1, 2, 3, 4}	Sinusoidal jitter tolerance (peak-to-peak)	—	—	—	0.11	UI
J _{RX_TJ} ^{1, 2, 3, 4}	Total jitter tolerance (peak-to-peak)	—	—	—	0.71	UI
T _{RX_EYE}	Receiver eye opening	—	0.29	—	—	UI

Notes:

1. Total jitter includes deterministic jitter, random jitter and sinusoidal jitter.
2. Jitter values are measured with each high-speed input AC coupled into a 50 Ω impedance.
3. Jitter and skew are specified between differential crossings of the 50% threshold of the reference signal.
4. Jitter tolerance, Differential Input Sensitivity and Receiver Eye Opening parameters are characterized when Full Rx Equalization is enabled.

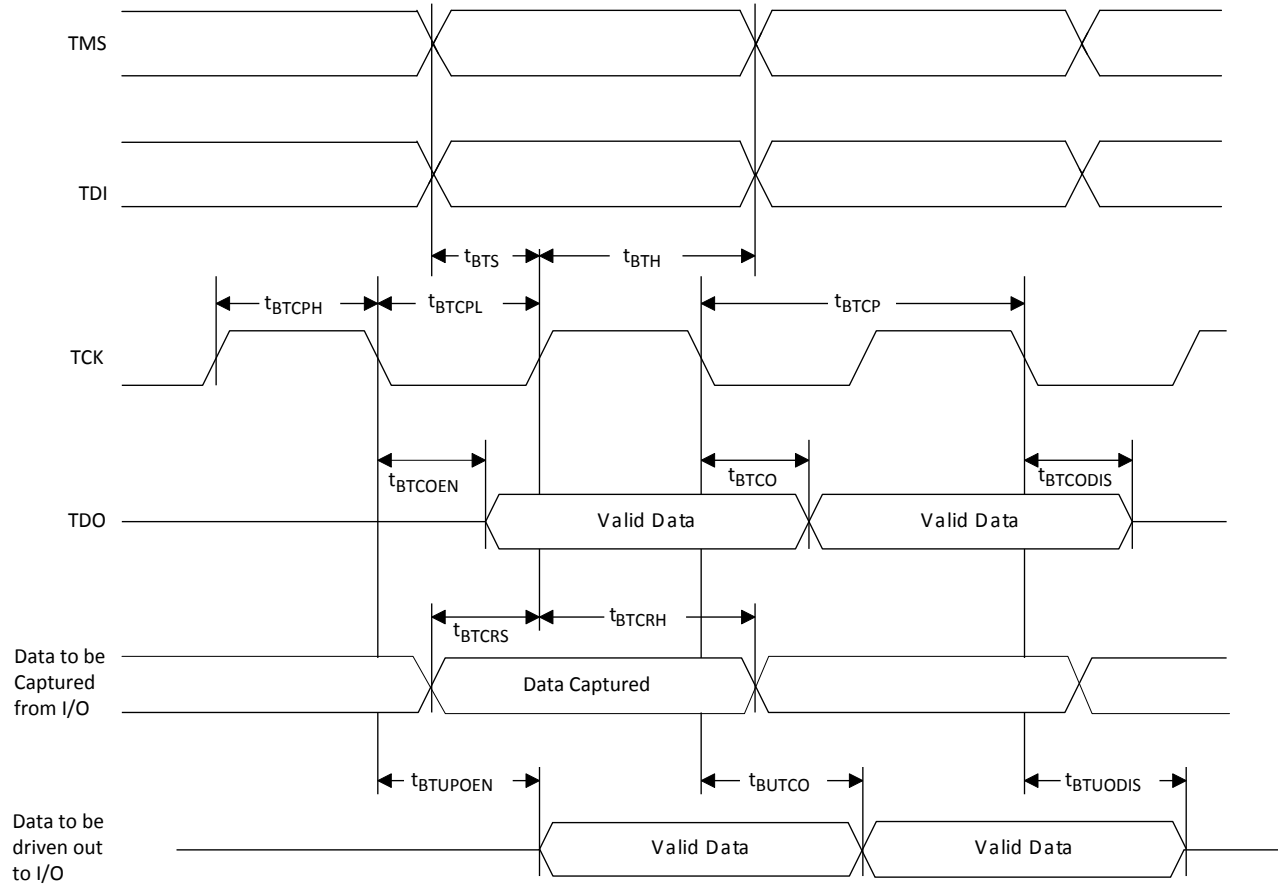
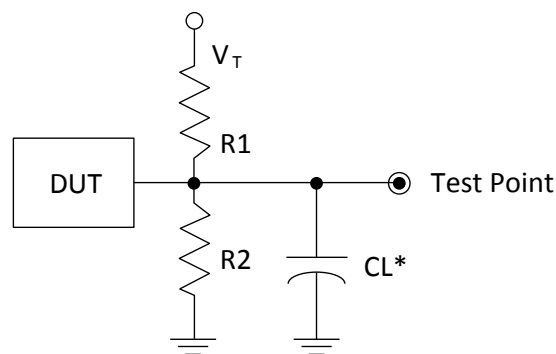


Figure 3.23. JTAG Port Timing Waveforms

3.33. Switching Test Conditions

Figure 3.24 shows the output test load that is used for AC testing. The specific values for resistance, capacitance, voltage, and other test conditions are listed in Table 3.44.



*CL Includes Test Fixture and Probe Capacitance

Figure 3.24. Output Test Load, LVTTTL and LVCMOS Standards

Signal Name	I/O	Description
PLL, DLL and Clock Functions (Continued)		
[L/R]DQS[group_num]	I/O	DQS input/output pads: T (top), R (right), group_num = ball number associated with DQS[T] pin.
[T/R]]DQ[group_num]	I/O	DQ input/output pads: T (top), R (right), group_num = ball number associated with DQS[T] pin.
Test and Programming (Dedicated Pins)		
TMS	I	Test Mode Select input, used to control the 1149.1 state machine. Pull-up is enabled during configuration. This is a dedicated input pin.
TCK	I	Test Clock input pin, used to clock the 1149.1 state machine. No pull-up enabled. This is a dedicated input pin.
TDI	I	Test Data in pin. Used to load data into device using 1149.1 state machine. After power-up, this TAP port can be activated for configuration by sending appropriate command. (Note: once a configuration port is selected it is locked. Another configuration port cannot be selected until the power-up sequence). Pull-up is enabled during configuration. This is a dedicated input pin.
TDO	O	Output pin. Test Data Out pin used to shift data out of a device using 1149.1. This is a dedicated output pin.
Configuration Pads (Used during sysCONFIG)		
CFG[2:0]	I	Mode pins used to specify configuration mode values latched on rising edge of INITN. During configuration, a pull-up is enabled. These are dedicated pins.
INITN	I/O	Open Drain pin. Indicates the FPGA is ready to be configured. During configuration, a pull-up is enabled. This is a dedicated pin.
PROGRAMN	I	Initiates configuration sequence when asserted low. This pin always has an active pull-up. This is a dedicated pin.
DONE	I/O	Open Drain pin. Indicates that the configuration sequence is complete, and the startup sequence is in progress. This is a dedicated pin.
CCLK	I/O	Input Configuration Clock for configuring an FPGA in Slave SPI, Serial, and CPU modes. Output Configuration Clock for configuring an FPGA in Master configuration modes (Master SPI, Master Serial). This is a dedicated pin.
HOLDN/DI/BUSY/CSSPIN/CEN	I/O	Parallel configuration mode busy indicator. SPI/SPI mode data output. This is a shared I/O pin. This is a shared I/O pin. When not in configuration, it can be used as general purpose I/O pin.
CSN/SN	I/O	Parallel configuration mode active-low chip select. Slave SPI chip select. This is a shared I/O pin. When not in configuration, it can be used as general purpose I/O pin.
CS1N	I	Parallel configuration mode active-low chip select. This is a shared I/O pin. When not in configuration, it can be used as general purpose I/O pin.
WRITEN	I	Write enable for parallel configuration modes. This is a shared I/O pin. When not in configuration, it can be used as general purpose I/O pin.
DOUT/CSO	O	Serial data output. Chip select output. SPI/SPI mode chip select. This is a shared I/O pin. When not in configuration, it can be used as general purpose I/O pin.
DO/MOSI/IOO	I/O	Parallel configuration I/O. Open drain during configuration. When in SPI modes, it is an output in Master mode, and input in Slave mode. This is a shared I/O pin. When not in configuration, it can be used as general purpose I/O pin.

Part number	Grade	Package	Pins	Temp.	LUTs (K)	SERDES
LFE5U-45F-8BG554C	–8	Lead free caBGA	554	Commercial	44	No
LFE5U-85F-6MG285C	–6	Lead free csfBGA	285	Commercial	84	No
LFE5U-85F-7MG285C	–7	Lead free csfBGA	285	Commercial	84	No
LFE5U-85F-8MG285C	–8	Lead free csfBGA	285	Commercial	84	No
LFE5U-85F-6BG381C	–6	Lead free caBGA	381	Commercial	84	No
LFE5U-85F-7BG381C	–7	Lead free caBGA	381	Commercial	84	No
LFE5U-85F-8BG381C	–8	Lead free caBGA	381	Commercial	84	No
LFE5U-85F-6BG554C	–6	Lead free caBGA	554	Commercial	84	No
LFE5U-85F-7BG554C	–7	Lead free caBGA	554	Commercial	84	No
LFE5U-85F-8BG554C	–8	Lead free caBGA	554	Commercial	84	No
LFE5U-85F-6BG756C	–6	Lead free caBGA	756	Commercial	84	No
LFE5U-85F-7BG756C	–7	Lead free caBGA	756	Commercial	84	No
LFE5U-85F-8BG756C	–8	Lead free caBGA	756	Commercial	84	No
LFE5UM-25F-6MG285C	–6	Lead free csfBGA	285	Commercial	24	Yes
LFE5UM-25F-7MG285C	–7	Lead free csfBGA	285	Commercial	24	Yes
LFE5UM-25F-8MG285C	–8	Lead free csfBGA	285	Commercial	24	Yes
LFE5UM-25F-6BG381C	–6	Lead free caBGA	381	Commercial	24	Yes
LFE5UM-25F-7BG381C	–7	Lead free caBGA	381	Commercial	24	Yes
LFE5UM-25F-8BG381C	–8	Lead free caBGA	381	Commercial	24	Yes
LFE5UM-45F-6MG285C	–6	Lead free csfBGA	285	Commercial	44	Yes
LFE5UM-45F-7MG285C	–7	Lead free csfBGA	285	Commercial	44	Yes
LFE5UM-45F-8MG285C	–8	Lead free csfBGA	285	Commercial	44	Yes
LFE5UM-45F-6BG381C	–6	Lead free caBGA	381	Commercial	44	Yes
LFE5UM-45F-7BG381C	–7	Lead free caBGA	381	Commercial	44	Yes
LFE5UM-45F-8BG381C	–8	Lead free caBGA	381	Commercial	44	Yes
LFE5UM-45F-6BG554C	–6	Lead free caBGA	554	Commercial	44	Yes
LFE5UM-45F-7BG554C	–7	Lead free caBGA	554	Commercial	44	Yes
LFE5UM-45F-8BG554C	–8	Lead free caBGA	554	Commercial	44	Yes
LFE5UM-85F-6MG285C	–6	Lead free csfBGA	285	Commercial	84	Yes
LFE5UM-85F-7MG285C	–7	Lead free csfBGA	285	Commercial	84	Yes
LFE5UM-85F-8MG285C	–8	Lead free csfBGA	285	Commercial	84	Yes
LFE5UM-85F-6BG381C	–6	Lead free caBGA	381	Commercial	84	Yes
LFE5UM-85F-7BG381C	–7	Lead free caBGA	381	Commercial	84	Yes
LFE5UM-85F-8BG381C	–8	Lead free caBGA	381	Commercial	84	Yes
LFE5UM-85F-6BG554C	–6	Lead free caBGA	554	Commercial	84	Yes
LFE5UM-85F-7BG554C	–7	Lead free caBGA	554	Commercial	84	Yes
LFE5UM-85F-8BG554C	–8	Lead free caBGA	554	Commercial	84	Yes
LFE5UM-85F-6BG756C	–6	Lead free caBGA	756	Commercial	84	Yes
LFE5UM-85F-7BG756C	–7	Lead free caBGA	756	Commercial	84	Yes
LFE5UM-85F-8BG756C	–8	Lead free caBGA	756	Commercial	84	Yes
LFE5UM5G-25F-8MG285C	–8	Lead free csfBGA	285	Commercial	24	Yes
LFE5UM5G-25F-8BG381C	–8	Lead free caBGA	381	Commercial	24	Yes
LFE5UM5G-45F-8MG285C	–8	Lead free csfBGA	285	Commercial	44	Yes
LFE5UM5G-45F-8BG381C	–8	Lead free caBGA	381	Commercial	44	Yes
LFE5UM5G-45F-8BG554C	–8	Lead free caBGA	554	Commercial	44	Yes
LFE5UM5G-85F-8MG285C	–8	Lead free csfBGA	285	Commercial	84	Yes

Part number	Grade	Package	Pins	Temp.	LUTs (K)	SERDES
LFE5U-85F-6BG756I	–6	Lead free caBGA	756	Industrial	84	No
LFE5U-85F-7BG756I	–7	Lead free caBGA	756	Industrial	84	No
LFE5U-85F-8BG756I	–8	Lead free caBGA	756	Industrial	84	No
LFE5UM-25F-6MG285I	–6	Lead free csfBGA	285	Industrial	24	Yes
LFE5UM-25F-7MG285I	–7	Lead free csfBGA	285	Industrial	24	Yes
LFE5UM-25F-8MG285I	–8	Lead free csfBGA	285	Industrial	24	Yes
LFE5UM-25F-6BG381I	–6	Lead free caBGA	381	Industrial	24	Yes
LFE5UM-25F-7BG381I	–7	Lead free caBGA	381	Industrial	24	Yes
LFE5UM-25F-8BG381I	–8	Lead free caBGA	381	Industrial	24	Yes
LFE5UM-45F-6MG285I	–6	Lead free csfBGA	285	Industrial	44	Yes
LFE5UM-45F-7MG285I	–7	Lead free csfBGA	285	Industrial	44	Yes
LFE5UM-45F-8MG285I	–8	Lead free csfBGA	285	Industrial	44	Yes
LFE5UM-45F-6BG381I	–6	Lead free caBGA	381	Industrial	44	Yes
LFE5UM-45F-7BG381I	–7	Lead free caBGA	381	Industrial	44	Yes
LFE5UM-45F-8BG381I	–8	Lead free caBGA	381	Industrial	44	Yes
LFE5UM-45F-6BG554I	–6	Lead free caBGA	554	Industrial	44	Yes
LFE5UM-45F-7BG554I	–7	Lead free caBGA	554	Industrial	44	Yes
LFE5UM-45F-8BG554I	–8	Lead free caBGA	554	Industrial	44	Yes
LFE5UM-85F-6MG285I	–6	Lead free csfBGA	285	Industrial	84	Yes
LFE5UM-85F-7MG285I	–7	Lead free csfBGA	285	Industrial	84	Yes
LFE5UM-85F-8MG285I	–8	Lead free csfBGA	285	Industrial	84	Yes
LFE5UM-85F-6BG381I	–6	Lead free caBGA	381	Industrial	84	Yes
LFE5UM-85F-7BG381I	–7	Lead free caBGA	381	Industrial	84	Yes
LFE5UM-85F-8BG381I	–8	Lead free caBGA	381	Industrial	84	Yes
LFE5UM-85F-6BG554I	–6	Lead free caBGA	554	Industrial	84	Yes
LFE5UM-85F-7BG554I	–7	Lead free caBGA	554	Industrial	84	Yes
LFE5UM-85F-8BG554I	–8	Lead free caBGA	554	Industrial	84	Yes
LFE5UM-85F-6BG756I	–6	Lead free caBGA	756	Industrial	84	Yes
LFE5UM-85F-7BG756I	–7	Lead free caBGA	756	Industrial	84	Yes
LFE5UM-85F-8BG756I	–8	Lead free caBGA	756	Industrial	84	Yes
LFE5UM5G-25F-8MG285I	–8	Lead free csfBGA	285	Industrial	24	Yes
LFE5UM5G-25F-8BG381I	–8	Lead free caBGA	381	Industrial	24	Yes
LFE5UM5G-45F-8MG285I	–8	Lead free csfBGA	285	Industrial	44	Yes
LFE5UM5G-45F-8BG381I	–8	Lead free caBGA	381	Industrial	44	Yes
LFE5UM5G-45F-8BG554I	–8	Lead free caBGA	554	Industrial	44	Yes
LFE5UM5G-85F-8MG285I	–8	Lead free csfBGA	285	Industrial	84	Yes
LFE5UM5G-85F-8BG381I	–8	Lead free caBGA	381	Industrial	84	Yes
LFE5UM5G-85F-8BG554I	–8	Lead free caBGA	554	Industrial	84	Yes
LFE5UM5G-85F-8BG756I	–8	Lead free caBGA	756	Industrial	84	Yes

Supplemental Information

For Further Information

A variety of technical notes for the ECP5/ECP5-5G family are available.

- [High-Speed PCB Design Considerations \(TN1033\)](#)
- [Transmission of High-Speed Serial Signals Over Common Cable Media \(TN1066\)](#)
- [PCB Layout Recommendations for BGA Packages \(TN1074\)](#)
- [Minimizing System Interruption During Configuration Using TransFR Technology \(TN1087\)](#)
- [Electrical Recommendations for Lattice SERDES \(FPGA-TN-02077\)](#)
- [LatticeECP3, ECP-5 and ECP5-5G Soft Error Detection \(SED\)/Correction \(SEC\) Usage Guide \(TN1184\)](#)
- [Using TraceID \(TN1207\)](#)
- [Sub-LVDS Signaling Using Lattice Devices \(TN1210\)](#)
- [Advanced Security Encryption Key Programming Guide for ECP5, ECP5-5G, LatticeECP3, and LatticeECP2/MS Devices \(TN1215\)](#)
- [LatticeECP3, LatticeECP2/M, ECP5 and ECP5-5G Dual Boot and Multiple Boot Feature \(TN1216\)](#)
- [ECP5 and ECP5-5G sysCONFIG Usage Guide \(TN1260\)](#)
- [ECP5 and ECP5-5G SERDES/PCS Usage Guide \(TN1261\)](#)
- [ECP5 and ECP5-5G sysIO Usage Guide \(TN1262\)](#)
- [ECP5 and ECP5-5G sysClock PLL/DLL Design and Usage Guide \(TN1263\)](#)
- [ECP5 and ECP5-5G Memory Usage Guide \(TN1264\)](#)
- [ECP5 and ECP5-5G High-Speed I/O Interface \(TN1265\)](#)
- [Power Consumption and Management for ECP5 and ECP5-5G Devices \(TN1266\)](#)
- [ECP5 and ECP5-5G sysDSP Usage Guide \(TN1267\)](#)
- [ECP5 and ECP5-5G Hardware Checklist \(FPGA-TN-02038\)](#)
- [Solder Reflow Guide for Surface Mount Devices \(FPGA-TN-02041\)](#)
- [ECP5 and ECP5-5G PCI Express Soft IP Ease of Use Guidelines \(FPGA-TN-02045\)](#)
- [Programming External SPI Flash through JTAG for ECP5/ECP5-5G \(FPGA-TN-02050\)](#)
- [Adding Scalable Power and Thermal Management to ECP5 Using L-ASC10 \(AN6095\)](#)

For further information on interface standards refer to the following websites:

- JEDEC Standards (LVTTTL, LVCMOS, SSTL): www.jedec.org
- PCI: www.pcisig.com

(Continued)

Date	Version	Section	Change Summary
April 2017	1.7	All	Changed document number from DS1044 to FPGA-DS-02012.
		General Description	Updated Features section. Changed “1.1 V core power supply” to “1.1 V core power supply for ECP5, 1.2 V core power supply for ECP5UM5G”.
		Architecture	Updated Overview section. Change “The ECP5/ECP5-5G devices use 1.1 V as their core voltage” to “The ECP5 devices use 1.1V, ECP5UM5G devices use 1.2V as their core voltage”
		DC and Switching Characteristics	Updated Table 3.2. Recommended Operating Conditions Added ECP5-5G on VCC to be 1.2V +/- 5% Added ECP5-5G on VCCA to be 1.2V +/- 3% Updated Table 3.8. ECP5/ECP5-5G Supply Current (Standby) Changed “Core Power Supply Current” for ICC on LFE5UM5G devices Changed “SERDES Power Supply Current (Per Dual)” for ICCA on LFE5UM5G devices Updated Table 3.20. Register-to-Register Performance. Remove “(DDR/SDR)” from DSP Function Changed DSP functions to 225 MHz
		Pinout Information	Update Section 4.1 Signal Description. Revised Vcc Description to “Power supply pins for core logic. Dedicated pins. VCC = 1.1 V (ECP5), 1.2 V (ECP5UM5G)”
February 2016	1.6	All	Changed document status from Preliminary to Final.
		General Description	Updated Features section. Changed “24K to 84K LUTs” to “12K to 84K LUTs”. Added LFE5U-12 column to Table 1.1. ECP5 and ECP5-5G Family Selection Guide.
		DC and Switching Characteristics	Updated Power up Sequence section. Identified typical ICC current for specific devices in Table 3.8. ECP5/ECP5-5G Supply Current (Standby). Updated values in Table 3.9. ECP5. Updated values in Table 3.10. ECP5-5G. Added values to –8 Timing column of Table 3.19. Pin-to-Pin Performance. Added values to –8 Timing column of Table 3.20. Register-to-Register Performance. Changed LFE5-45 to All Devices in Table 3.22. ECP5/ECP5-5G External Switching Characteristics. Added table notes to Table 3.31. PCIe (5 Gb/s). Added table note to Table 3.32. CPRI LV2 E.48 Electrical and Timing Characteristics.
		Pinout Information	Added LFE5U-12 column to the table in LFE5U section.
		Ordering Information	Updated LFE5U in ECP5/ECP5-5G Part Number Description section: added 12 F = 12K LUTs to Logic Capacity. Added LFE5U-12F information to Ordering Part Numbers section.

(Continued)

Date	Version	Section	Change Summary
August 2014	1.2	DC and Switching Characteristics	SERDES High-Speed Data Receiver section. Updated Table 3.26. Serial Input Data Specifications, Table 3.28. Receiver Total Jitter Tolerance Specification, and Table 3.29. External Reference Clock Specification (refclkp/refclk).
			Modified section heading to XXAU/CPRI LV E.30 Electrical and Timing Characteristics. Updated Table 3.33 Transmit and Table 3.34. Receive and Jitter Tolerance.
			Modified section heading to CPRI LV E.24 Electrical and Timing Characteristics. Updated Table 3.35. Transmit and Table 3.36. Receive and Jitter Tolerance.
			Modified section heading to Gigabit Ethernet/SGMII/CPRI LV E.12 Electrical and Timing Characteristics. Updated Table 3.37. Transmit and Table 3.38. Receive and Jitter Tolerance.
June 2014	1.1	Ordering Information	Updated ECP5/ECP5-5G Part Number Description and Ordering Part Numbers sections.
March 2014	1.0	All	Initial release.